FTD-HT-23-711-71

FOREIGN TECHNOLOGY DIVISION

LOW-CAPACITY MICROWAVE COMMUNICATION LINKS

by

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14

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)
Foreign Technology Division
Air Force Systems Command
U. S. Air Force

2a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b. GROUP

3. REPORT TITLE
LOW-CAPACITY MICROWAVE COMMUNICATION LINKS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Translation

5. AUTHOR(S) (First name, middle initial, last name)
Lipsman, F. P.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
1970	9	7

8a. CONTRACT OR GRANT NO.
F33657-71-D-0142

b. PROJECT NO.

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)
FTD-HT-23-711-71

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT
Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
Foreign Technology Division
Wright-Patterson AFB, Ohio

13. ABSTRACT

The author discusses various uses for low-capacity microwave links (LCML). Unlike multichannel (long-line) systems, LCML's are found in both fixed (stationary) and transportable versions, including the highly mobile kind installed on a variety of motor vehicles. An essential LCML characteristic is that these are, as a rule, single-trunk links capable of being rapidly returned over a wide frequency band, while in most cases multi-channel radio-relay lines operate exclusively on fixed frequencies assigned to each trunk during the manufacturing stage at the plant. The author points out that the introduction of the time-division principle to LCML's has proven convenient, but he also indicates certain shortcomings of systems with time division of the channels. Soviet scientists have studied a system featuring a technique known as interval pulse-time modulation (IPTM), which utilizes fully the statistical properties of speech traffic, including occupancy (busy-condition) statistics (as in FM systems).

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UNCLASSIFIED
Security Classification

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Security Classification

KEY WORDS

Microwave
Microwave Delay
Microwave Power Sta
Microwave Technolog

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...overall report is classified)

REPORT SECURITY CLASSIFICATION

UNCLASSIFIED

GROUP

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PAGES	7b. NO. OF REFS
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KEY WORDS	LINK A		LINK B		LINK C	
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Microwave Power Stabilization						
Microwave Technology						

UNCLASSIFIED
Security Classification

FTD-HT-23-711-71

EDITED TRANSLATION

LOW-CAPACITY MICROWAVE COMMUNICATION LINKS

By: F. P. Lipsman

English pages: 9

Source: Antenny i Antennyye Ustroystva. Sbornik Statey (Antennas and Antenna Devices. Collection of Articles), 1970, pp 80-84

Translated under: Contract No. F 33657-71-C-0142

UR/0000-70-000-000

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FTD-HT-23-711-71 Date 26 Oct 1971

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* ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

F. P. Lipsman

LOW-CAPACITY MICROWAVE COMMUNICATION LINKS

The first radio-relay (microwave) links, which thirty years ago first came to be used as a new means of radio communication, had a limited channel capability. The simplest of these links were in effect conventional ultra-short-wave radio stations using relay facilities to achieve increased range. Experience in the operation of these relay stations pointed to the advisability of employing superhigh frequencies for the establishment of long-line radio links and showed the construction and operation of such stations to be not merely not overly burdensome, but on occasion even advantageous as a means of maintaining communications both between the two terminal sites as well as with the areas surrounding the intermediate stations.

Since the moment of its inception, microwave communication has developed along two principal lines: a continuing increase in the number of channels transmitted on a single carrier frequency and the exploitation of ever higher frequency bands. In modern microwave systems a single high-frequency trunk may handle as many as 600, 900, 1920, and even 2700 telephone channels. Despite this, however, low-capacity microwave links (LCML) have not lost their importance and continue to perform a vital function in the radio communications area.

The extremely broad class of LCML's includes microwave links operating within the limits of "line-of-sight" (as opposed to tropospheric links) with a capacity of as many as 60 channels, although this is, of course, an arbitrary

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breakdown. Equipment for such links is produced and operated in the USSR and in many countries of the world. The systems themselves cover an extraordinarily wide frequency band and differ markedly in channel capacity, circuitry, design, transmitter output, modulation modes, etc.. LCML's may be found with 2, 3, 4, 6, 7, 12, 24, 48, and 60 telephone channels operating in various portions of an enormous waveband stretching from 50 MHz to tens of gigaherz.

The reason for this profusion of LCML circuit arrangements, designs, and bands is to be found in the fact that many of these links are engineered for use only in special operational conditions - for example, microwave links for oblast-wide (regional) telephone-telegraph traffic differ considerably in terminal equipment design from rail-transport control circuits or gas and oil pipeline links. Nevertheless, despite the differences, there are certain common features specific to all LCML's which make it possible to discuss these systems as an independent and largely self-contained class of radio engineering facility.

A number of basic characteristics of low-capacity microwave links can be cited. One of these, of a structural nature, relates to the circumstance that, unlike multichannel (long-line) systems, LCML's are found in both fixed (stationary) and transportable versions, including the highly mobile kind installed on a variety of motor vehicles. In the rail transport and gas and oil pipeline sector, naturally, fixed links are called for; however, during the actual construction of these roads and pipelines, mobile microwave facilities are also needed to provide communications between the building organizations. There are substantial differences in the design and, occasionally, in the circuitry and equipment makeup of fixed and mobile LCML's.

Another systems feature of the LCML consists in its use not only of the classical methods of channel frequency-division and frequency modulation (SSB-FM), as adopted in multichannel long-line microwave circuits, but of channel time-division and a variety of pulse-modulation modes. Of the many known pulse-modulation modes, LCML's have employed only pulse-phase modulation (PPhM), pulse-code modulation (PCM), and delta-modulation [1, 2], which are used in conjunction with amplitude or frequency modulation of the SHF transmitter (for example, PPhM-AM or PCM-FM systems).

Finally, yet another essential LCML characteristic lies in the fact that these are, as a rule, single-trunk links capable of being rapidly retuned over a wide frequency band, while in most cases multichannel radio-relay lines operate exclusively on fixed frequencies assigned to each trunk during the manufacturing stage at the plant.

The introduction of the time-division principle to LCML's has proven convenient primarily because, with the channels divided on a time basis, messages transmitted over the link can be easily discriminated (inserted or dropped out) at the intermediate stations with no limitations whatever with respect to the number of discriminated channels and with no effect on their electrical parameters. This is an important feature on relatively short radio links designed for branched communication systems, but one which is virtually unnecessary in the case of multichannel long-line systems which require only the tapping of large groups of channels at a limited number of points.

An additional advantage of the time-division systems is that certain of them, such as, for example, those with PCM, show a far better noise-

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suppression characteristic than in the case of other modulation modes [1], plus the fact that with pulse transmission methods the effect on link operation of pulse interference can be reduced through the use of noise-resistant synchronization systems [3], the detection of false pulses, and the suppression of their effect.

Along with these positive features, however, attention should also be called to certain shortcomings of systems with time division of channels. These include, first and foremost, the fact that the noise-resistance to fluctuating interference in conventional time-division systems (other than those with PCM and delta-modulation) is somewhat less than in amplitude-modulated systems. Provided the number of channels is small, this difference is negligible; as the channelization increases it takes on greater significance, and in 24-channel systems with identical average transmitter output, antenna dimensions, receiver sensitivity, etc., the ratio of the power of the fluctuation noise in the telephone channels of a PPhM-AM system to the noise power in an SSB-FM system may, according to some sources [2, 4], attain values of 6.7—11.8.

The difference actually observable in real systems will be less than that indicated, as a consequence of the fact that in SSB-FM systems nonlinear transient noise is added to the fluctuation noise (whereas in PPhM-AM systems transient noise is intelligible, of low amplitude, and thus does not increase the fluctuation noise). Since FM systems are designed for optimum frequency deviation, the total noise power in the telephone channel will actually be 1.5—2 times greater because of nonlinear transients, and, consequently, the real noise power ratio in the telephone channels of the systems under

comparison will be no more than 3—5.

Another defect of the most widely encountered systems with channel time-division, such as, for example, certain pulse-code-modulation systems, is their failure to exploit the statistical properties of the messages transmitted (as in SSB-FM systems) and the fact that in order to achieve a prescribed signal/noise ratio in the telephone channels fairly steep pulse fronts must be transmitted. This latter circumstance results in PCM-AM systems occupying a larger frequency band than SSB-FM systems.

Finally, it is noteworthy that a characteristic of all systems with channel time-division and pulse modulation is their unsuitability for multichannel links having more than 24—28 channels. However, by partially exploiting the statistical properties of the voice message and employing instantaneous compander (pre-emphasis) techniques, the number of channels in a PCM system can be increased to 60, as in one of the systems produced by the Siemens firm. And even this does not exhaust the possibilities of time-division pulse-modulation systems.

Soviet scientists have studied a system featuring a technique known as interval pulse-time modulation (IPTM) [5], which utilizes fully the statistical properties of speech traffic, including occupancy (busy-condition) statistics (as in FM systems), as a result of which systems employing this form of modulation can accommodate as many as 100 or more channels. It would appear, however, that IPTM systems will not be used on branched communication networks because of the complexity of the group drop-and-insertion filters at the intermediate stations. IPTM systems can be most effectively used for links designed to transmit a large volume of voice traffic between two points (e.g.,

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The Soviet Union is the producer of a sizable quantity of low-capacity microwave equipment for national economic needs. Domestically produced LCML's are largely standardized as to electrical characteristics, particularly with respect to the specifications of their telephone channels, and for the most part operate in CCIR-recommended spectral regions. Soviet industry manufactures only those LCML types which are required in heavy quantities. Wherever there is no need for large-scale production of a particular kind of low-capacity microwave system because of a limited national-economic requirement, the equipment is purchased abroad, as in the case of the PPM-24/28 from Hungary, the M24-400 from Finland, and so on.

In the Soviet Union there has already been a turnover of several generations of limited-channel microwave systems. Our first FM-type LCML's, placed in full-scale production as early as 1949—1950, such as the RRS-1 radio link with frequency division of channels, frequency modulation, and a capacity of 2 telephone and 2 telegraph channels operating in the 60—70-MHz band, employed vacuum tubes throughout (1, 6). The first domestic decimeter multichannel pulse systems with PCM to be produced by our industry in large quantities were also of the tube-type. The next LCML generation featured extensive transistorization, although vacuum components were still retained in the SHF equipment. By way of example, one might cite the URL-24 - one of the second generation of domestic 24-channel decimeter-band systems (1, 7). We now have low-channel radio-relay systems which are transistorized throughout, including the SHF instrumentation.

One such LCML, designed for oblast-wide traffic, is the "Konteyner" /"Container"/ - an unattended, fully automatic FM link engineered for 12

telephone channels operating in the 400-MHz band. By employing high-power transistors together with varactor frequency multipliers, it was possible to achieve relatively high transmitter output and to ensure high-quality communications over compact antenna devices. The state of the semiconductor art makes possible the design of links in a variety of bands not only with frequency modulation, but also of pulse-type PCM, PPhM, and delta-modulation systems. An example of this class of microwave system is the highly compact Hungarian-developed six-channel DM-400/6 delta-modulation microwave system for operation in the 400-MHz band.

Within the limitations of a survey article of this kind it is naturally not possible to cite all the accomplishments which have been made in this area in the USSR and abroad, to say nothing of providing comprehensive technical specifications for the equipment presently in use. Still, some general trends in LCML development can be outlined.

It is now quite clear that the second generation of fully transistorized low-capacity microwave systems will be replaced by LCML's based on solid-state components and film technology. Although it is even now possible to build such systems, this is not always an economically sound approach and for this reason solid-state and film technology is being introduced into low-capacity microwave series production on a gradual basis, as production expands and the cost of these components comes down.

Cost, power-consumption, and size reduction, along with reliability enhancement, are not the only problems being studied by low-capacity microwave engineers. The very essence of the employment of these systems, consisting as it does in the inability to isolate them from numerous sources of inter-

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ference - since in most cases they handle engineering traffic and are therefore located in the immediate vicinity of industrial facilities - and in the continuous increase in the number of links and in the density of their installation, leads to the need to abandon the classic methods of transmission in favor of new methods which will be far less exposed to mutual interference and to noise in general. There is also the problem of optimizing the exploitation of the allocated bands, requiring that different LCML's be capable of interference-free operation in the same region on identical frequencies or that the frequency bands necessary for LCML operation be maximally compressed. These considerations, as well as the opportunities made available to designers by advanced semiconductor engineering, explain why LCML's are increasingly incorporating PCM-AM, PCM-FM, and PCM-RPT* systems for their high noise-resistance and relatively narrow band occupancy.

The PCM and delta-modulation systems which have developed in line with LCML advances are becoming more and more important. The technique of pulse coding and decoding has been perfected to the degree that it is even now possible to transmit by the PCM method virtually any message, including the group spectrum of 600 and more channel groups and even television signals. Efforts are being made to compress the frequency band required for microwave operation by transmitting the group spectrum of the multichannel message (SSB signals) by direct frequency shift to the transmission carrier. The research which has been carried out indicates that the problem of transmitting the signals of several LCML's on a single frequency is also soluble through

*RPT = relative phase telegraphy - Translator's Note.

the use of composite signals of complex form which can be recognized on the basis of definite attributes imparted during their formation - forms and addresses. The use of such complex, multidimensional signals in multi-channel long-line radio-relay links is unlikely. Low-channel links would seem to offer better prospects in this respect.

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Article received 16 January 1970